MOTIVATION

- Simulation of the performance of Micromegas detectors with realistic dimensions (InGrid Variant).
- Investigation of variation of electric field due to change in the cross-section of the mesh opening and other physical dimensions of the detector in detail.
- Estimation of resulting effect on the gain of the detector by obtaining the Townsend coefficient through the use of Magboltz.
- Study of other three dimensional effects such as the effects of proximity of hole edge, or the end of the detector itself.

Numerical Simulation : Use of GARFIELD

- **In each step : Needs the electromagnetic field.**
- **Earlier electromagnetic field estimated by either analytical solutions (for two dimensional devices) or commercial FEM packages such as MAXWELL, ANSYS, TOSCA, QUICKFIELD, FEMLAB etc.**

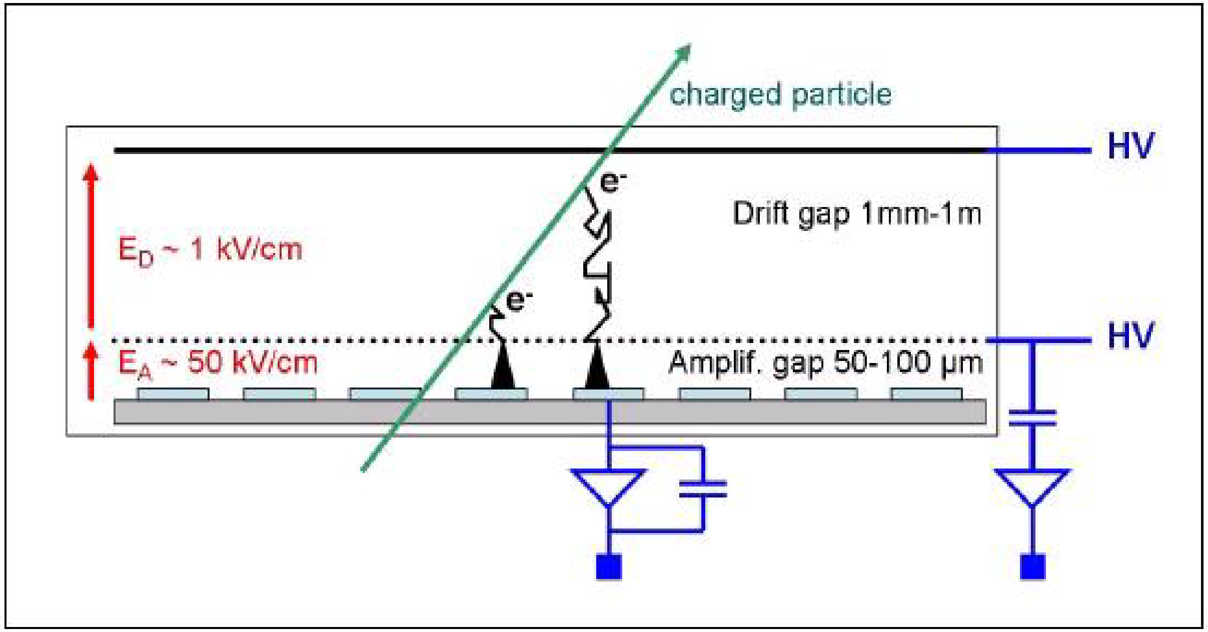
Present work :

GARFIELD ⊕ neBEM

GARFIELD[1] : To model the Micromegas detector

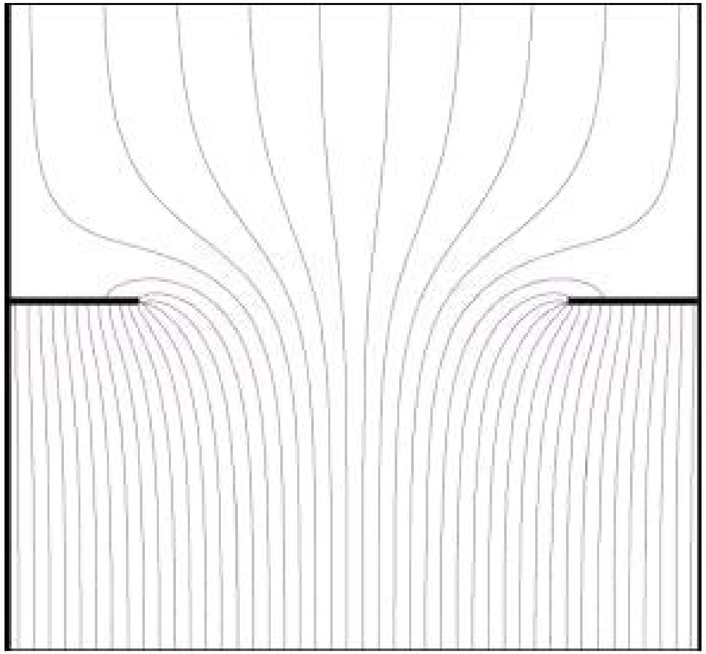
neBEM[2] : To calculate the electric field

[1] *garfield.web.cern.ch*
[2] *neBEM.web.cern.ch*



(a)

Operational principle of a Micromegas detector



(b)

Field line configuration in the amplification region

Reference :-
Maximilien Alexandre Chefdeville, Development of Micromegas-like gaseous detectors using a pixel readout chip as collecting anode, University of Amsterdam, PhD Thesis paper

Procedure

Using GARFIELD define a cell structure

⇓

A drift plane ;
A micromesh of one hole ;
An anode strip ;
A dielectric substrate ;

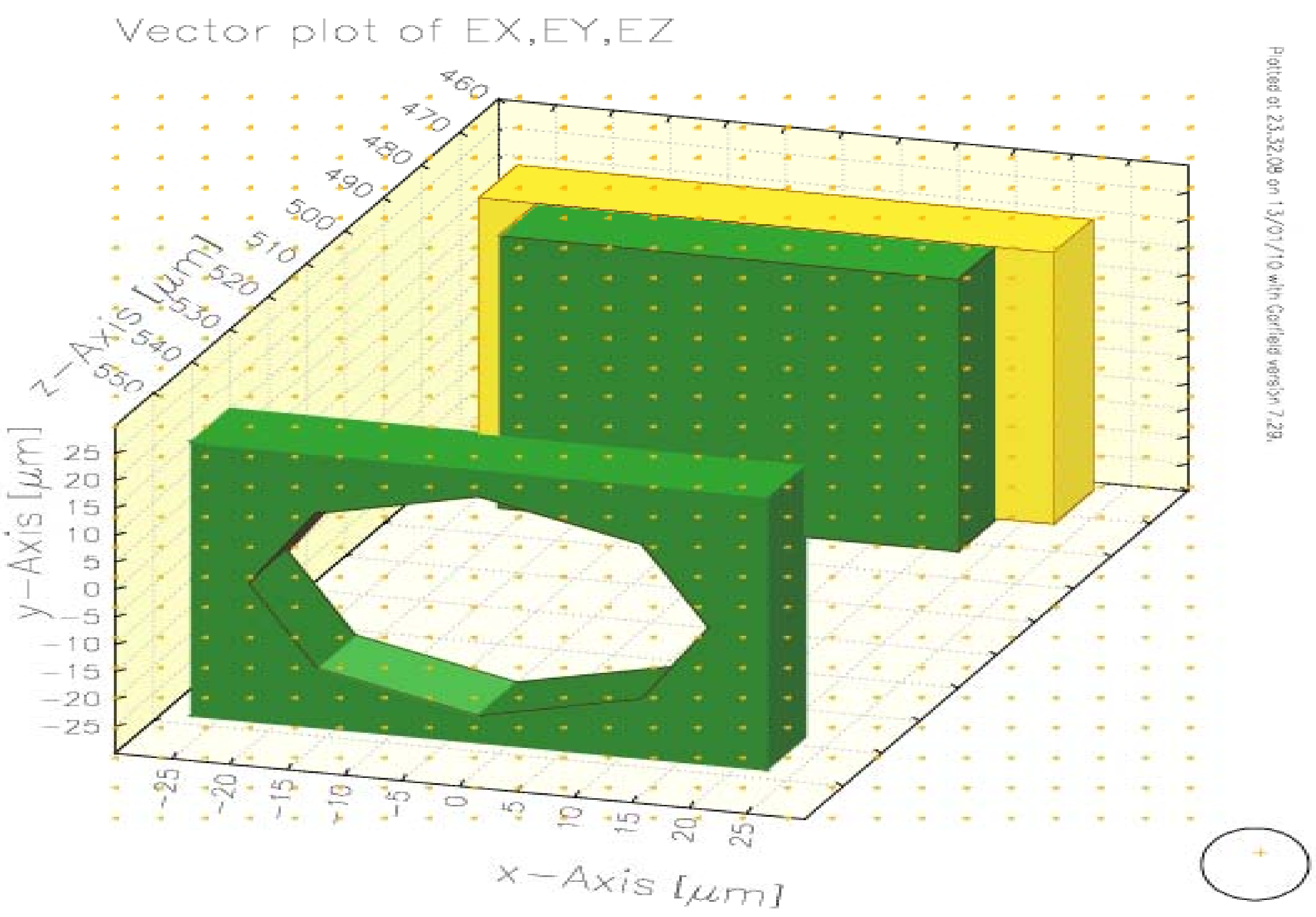
The Details of a typical cell :-

- ***The length of the drift region – 1600 micron***
- ***The length of the amplification region – 55 micron***
- ***The radius of the mesh hole – 20 micron***
- ***The drift plane voltage -1500 V***
- ***The mesh plane voltage -400 V***
- ***The anode strips are grounded***

Using neBEM

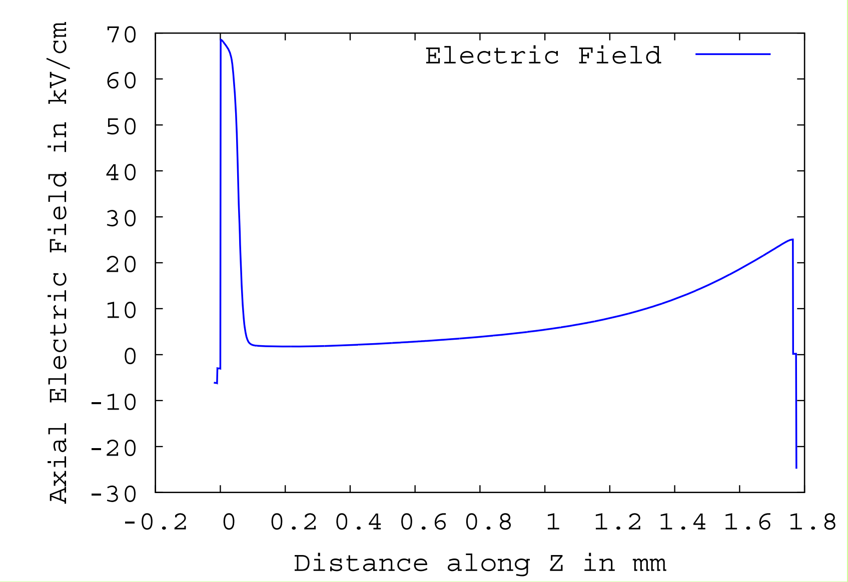
⇓

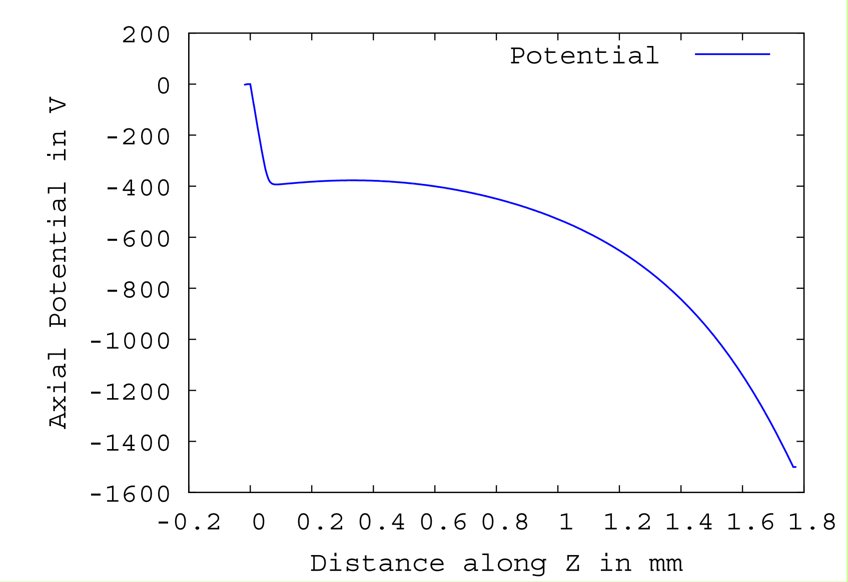
The whole cell structure is repeated along both positive and negative X – and Y- direction so that the pitch is 50 micron



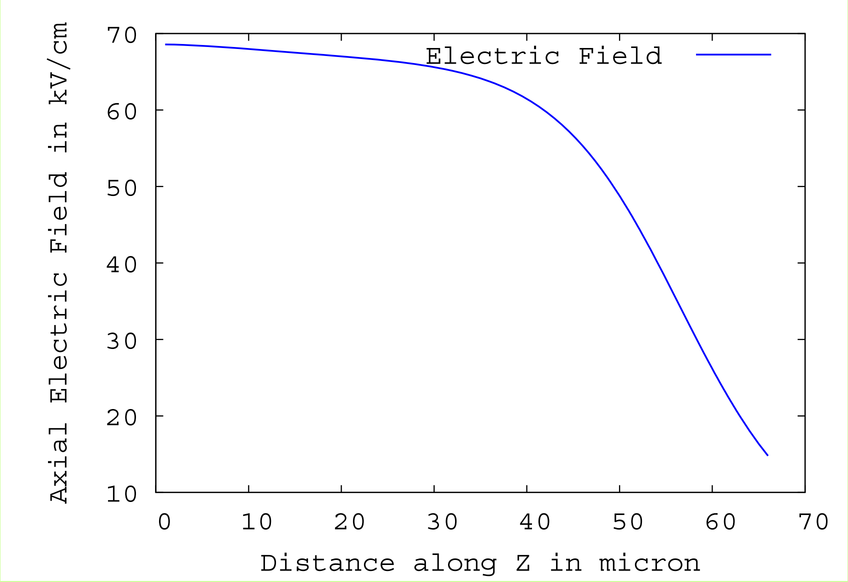
Vector plot of EX,EY,EZ
z–Axis [μm]
460
470
480
490
500
510
520
530
540
550
y–Axis [μm]
25
20
15
10
5
0
−5
−10
−15
−20
−25
x–Axis [μm]
Plotted at 23.32.08 on 13/01/10 with Garfield version 7.28.

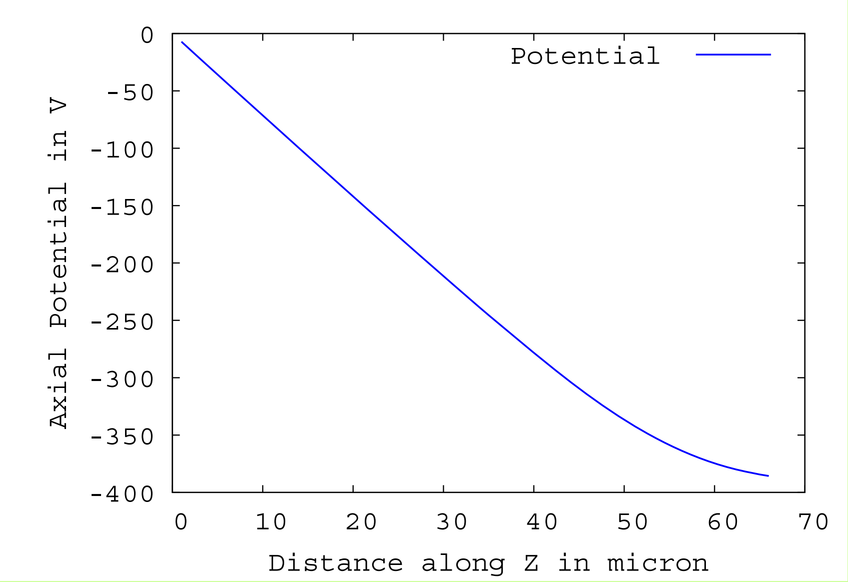
The axial electric field and potential for the whole cell

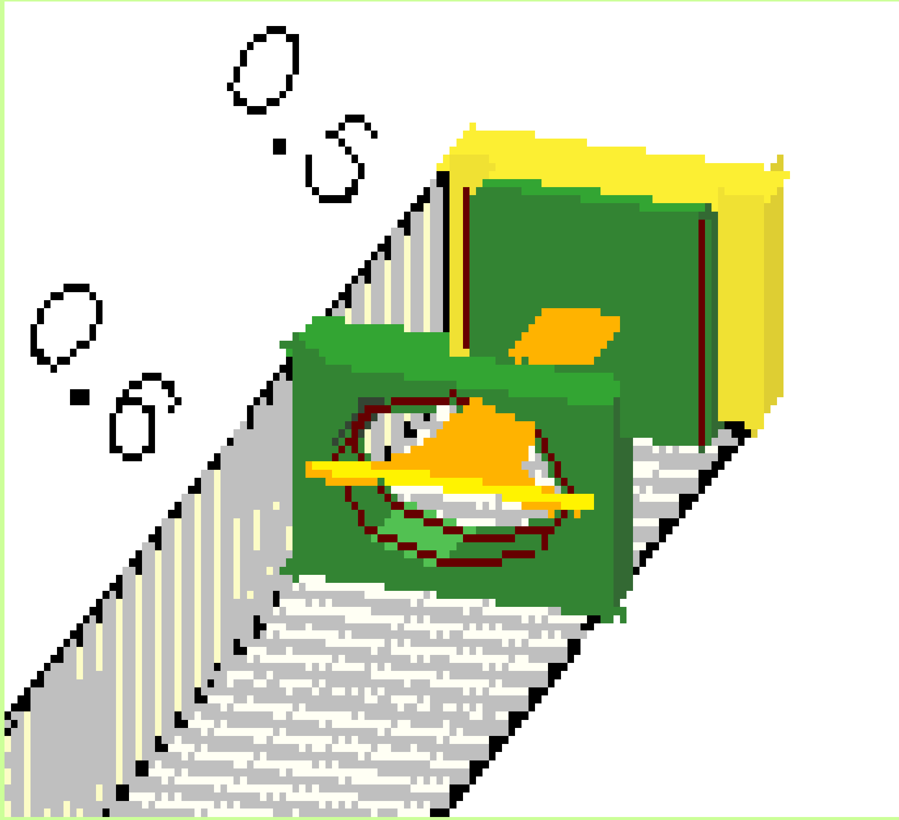




The axial electric field and potential for the amplification region

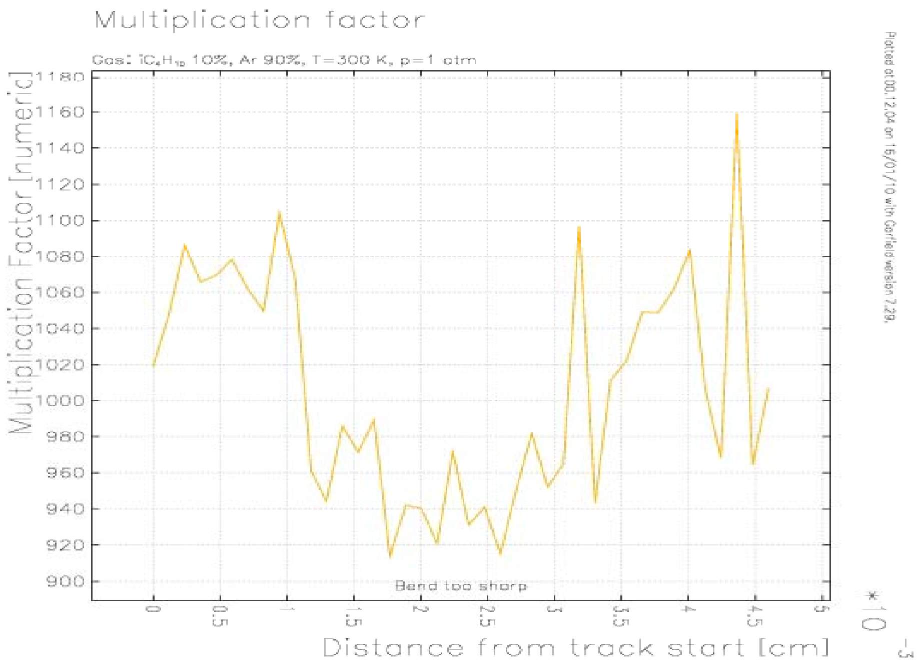






Drift line of those 40 electrons from the track to anode.

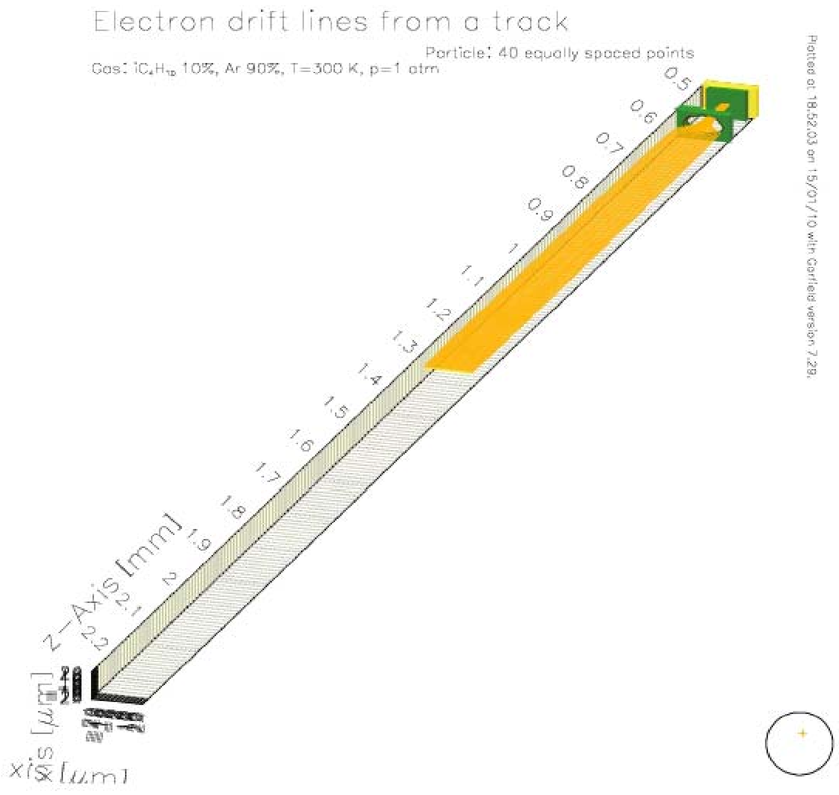
We define a track just above the mesh and assume 40 electrons are generated at first from the track.



Plot of the multiplication factor

On an average the gain ~ 970.

We define a track in the middle of drift region and assume 40 electrons are generated at first from the track.



Drift line of those 40 electrons from the track to anode.

Plot of the multiplication factor

On an average the gain ~ 1000.

The calculation of gain -- II

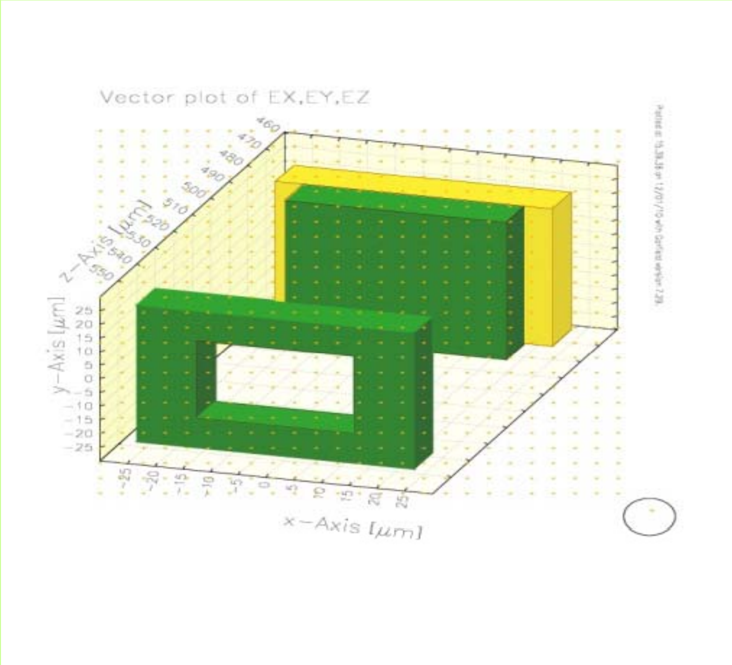
- Calculate electric field using neBEM
- Calculate Townsend Coefficient using Garfield
- Use Trapezoidal Rule to calculate the amplification factor $G = \exp(\int_0^z \alpha dz)$ along a prefixed line

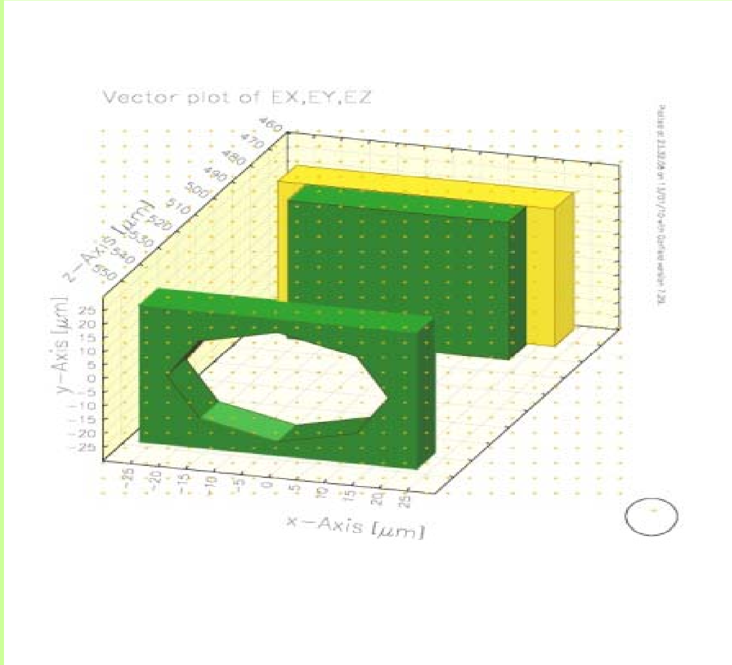
- For the track which is just above the mesh G = 875
- For the track which is in the middle of drift region, G = 880

The calculated gain in both methods (using Garfield and using the simpler trapezoidal integration) are almost equal.

Four Different hole shapes

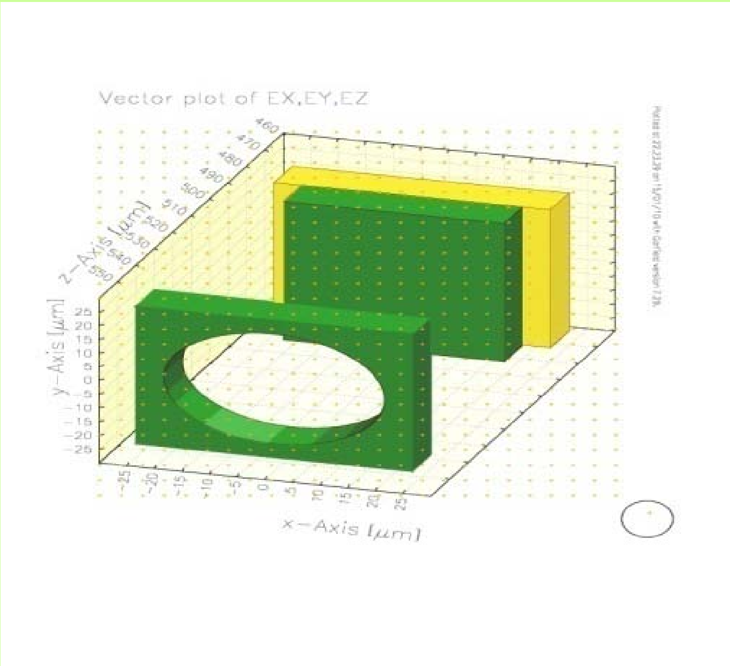
N=2

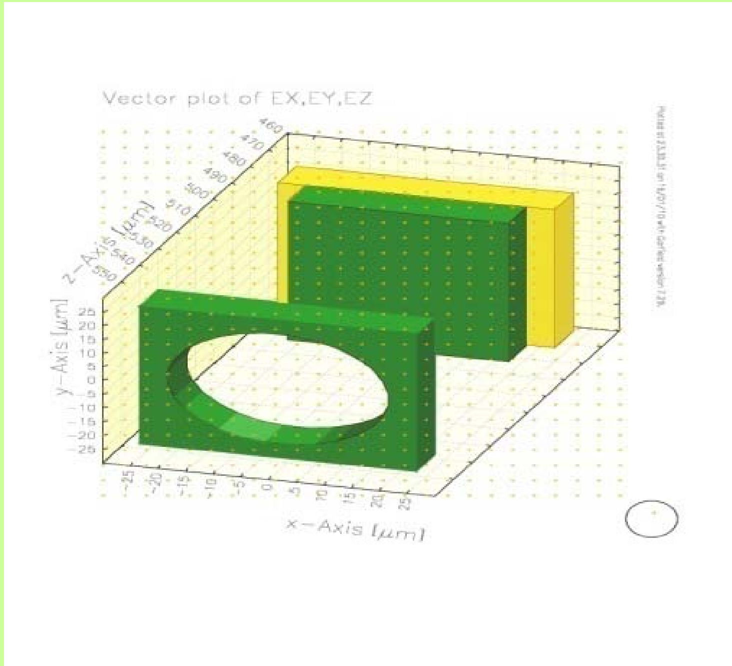




N=3

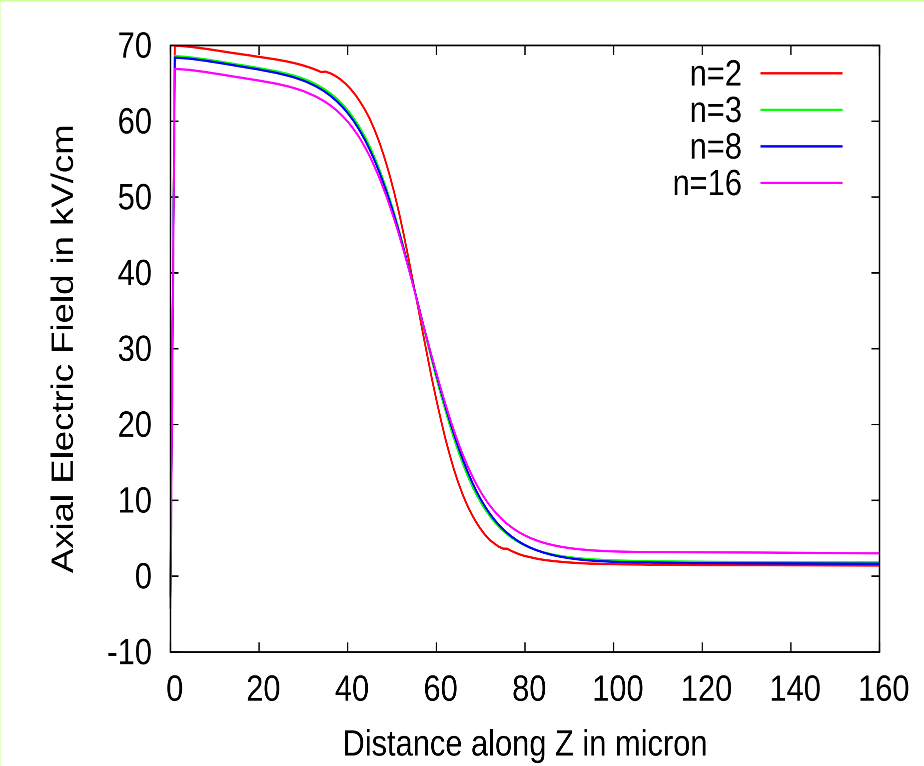
N=16





N=8

Variation of axial electric field in the amplification region and gain for Four different hole shapes

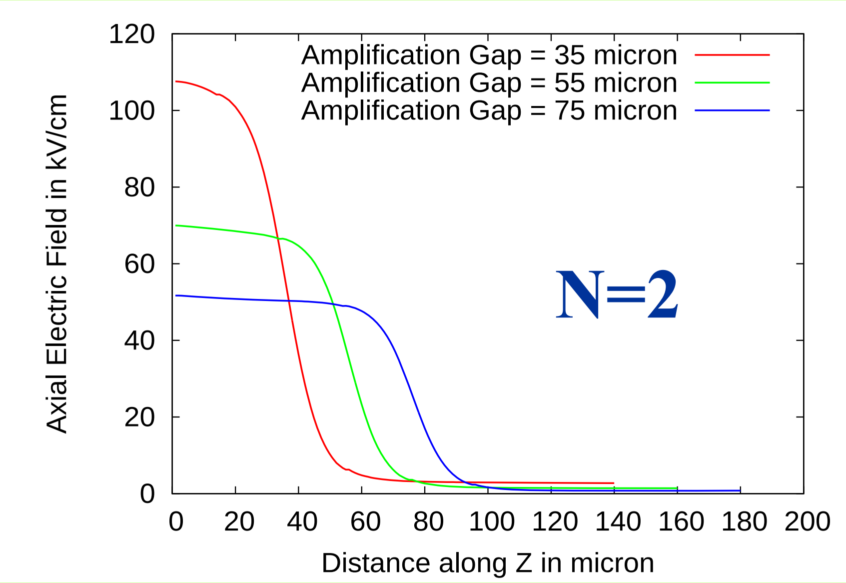


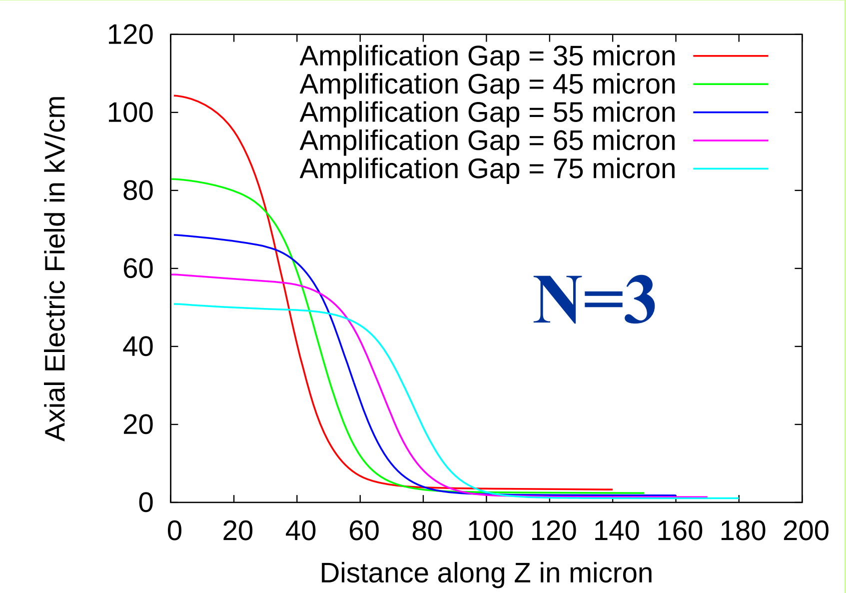
Shape of the hole	Gain using Garfield (when the track is just above the mesh)	Gain using Trapezoidal Integration method
N=2	1220	1124
N=3	970	875
N=8	890	846
N=16	770	709

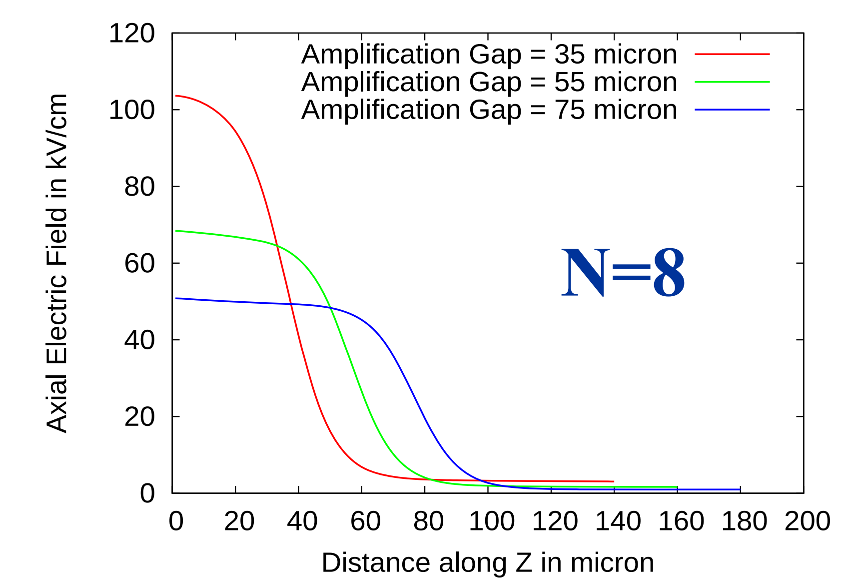
Effect of change of shape of hole :

- **From N=2 to N=16, the value of electric field has decreased.**
- **For N=3 and N=8, the values are almost same.**
- **The value of gain also decreases as we go from N=2 to N=16.**

Variation of axial electric field of the amplification region for different amplification gap and for three different hole shapes







As we increase the amplification gap, the electric field decreases.

For N=3, Variation of gain for different amplification gap

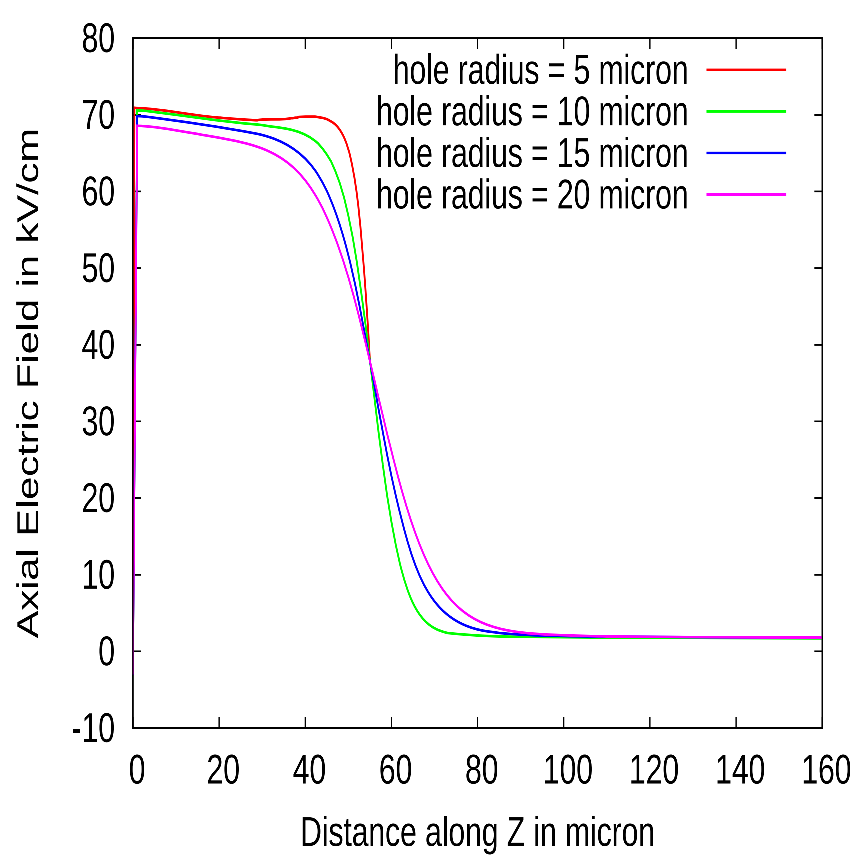
Amplification Gap in micron	Gain, Using Garfield (when the track is just above the mesh)	Gain, Using Trapezoidal Integration method
35	2500	2083
45	1550	1374
55	970	875
65	610	576
75	380	345

While in some experiments[1] it has been reported that there exists an optimum gap for maximizing the gain, in some other[2], the gain is found to increase as the gap is decreased. In our computations, we see the latter trend. This issue is possibly complicated and needs further investigation.

[1] NIM A 419 (1998) 239-250 doi:10.1016/S0168-9002(98)00865-1
[2] Jinst P02001 doi:10.1088/1748-0221/5/02/P02001

Variation of axial electric field in the amplification region and gain for different hole size

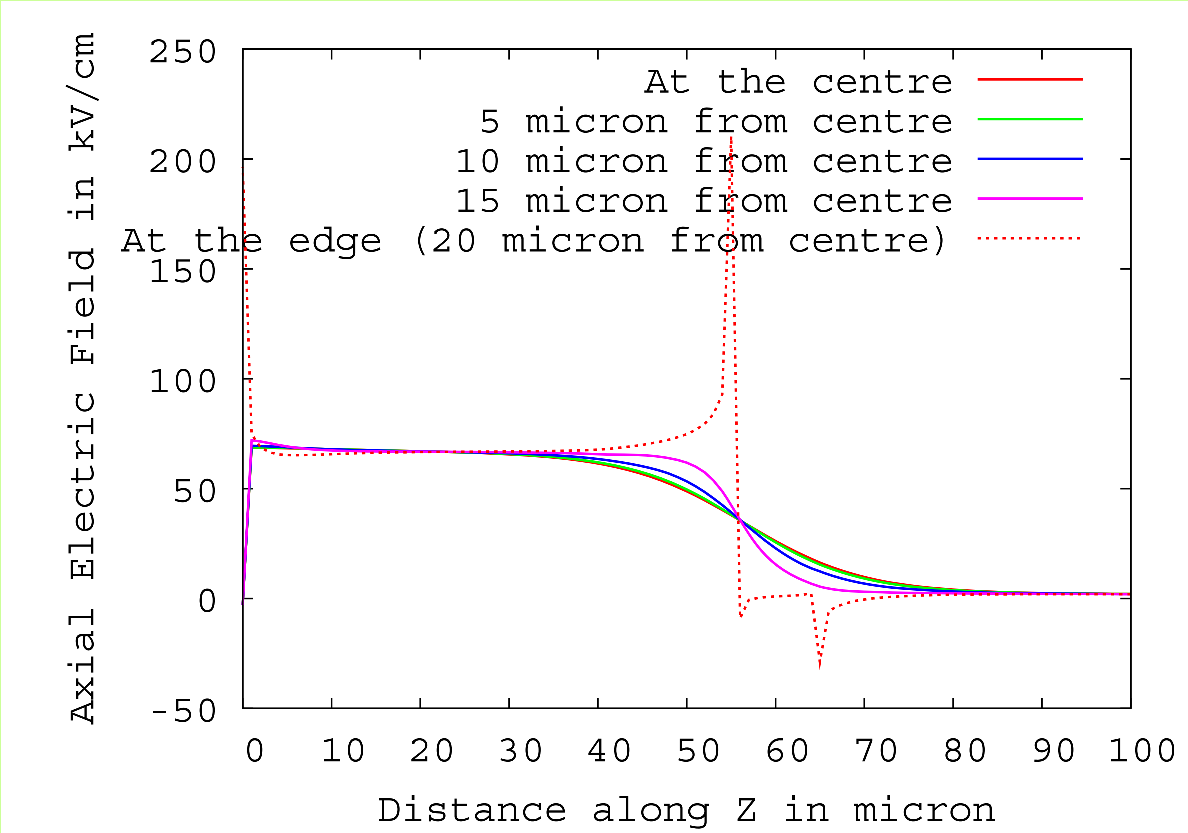
N=3
Amplification gap = 55 micron



Radius of the hole in micron	Gain using Garfield (when the track is just above the mesh)	Gain using Trapezoidal Integration method
5	1900	1735
10	1600	1417
15	1250	1115
20	970	875

Decrease the radius of the hole ➡ Distortion of electric field

Variation of axial electric field from the edge to the centre



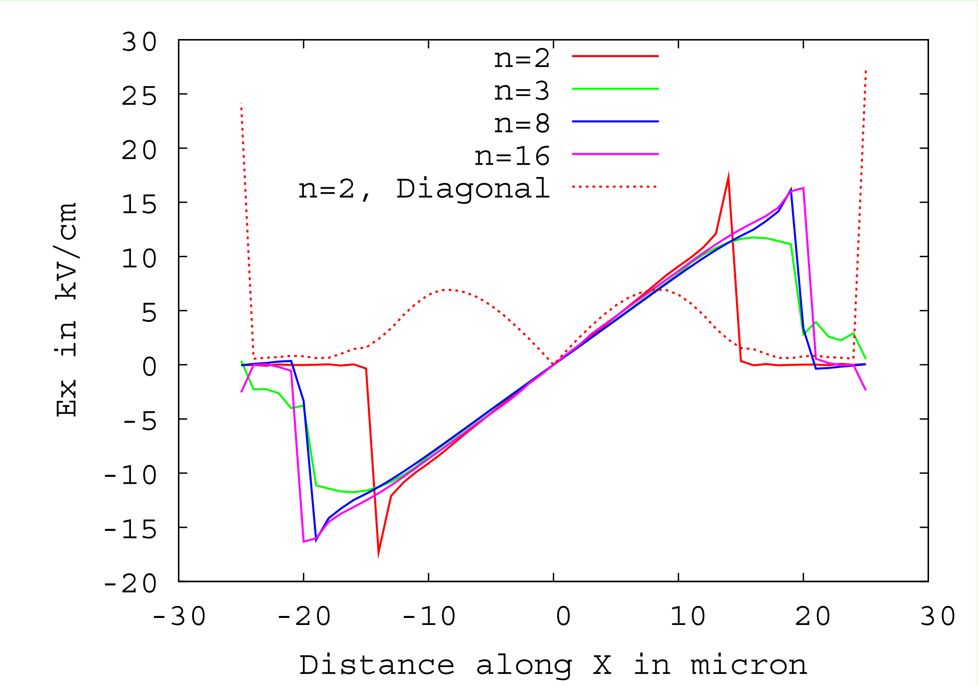
N = 3

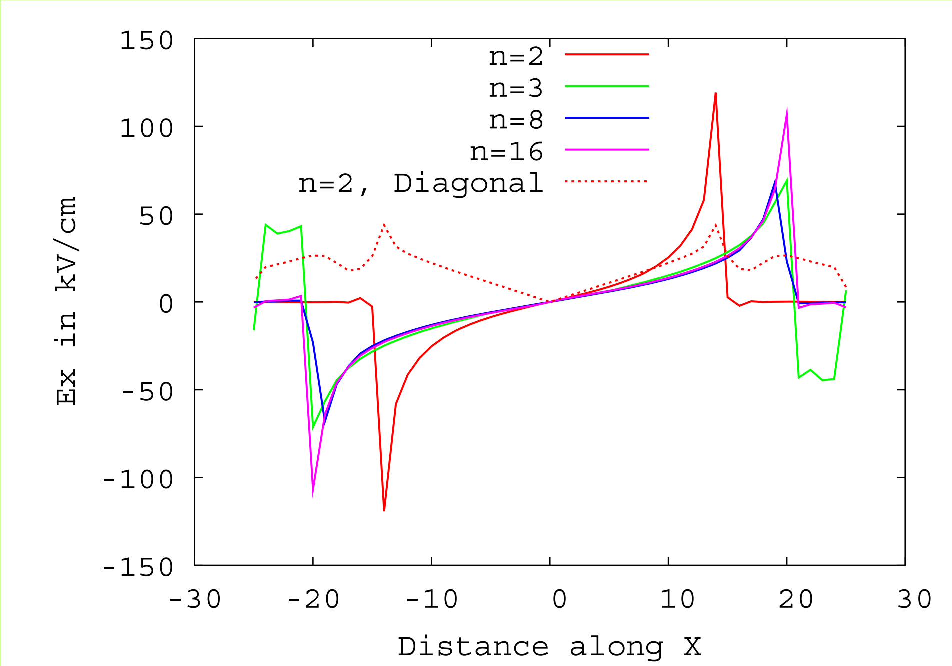
- **As we go from the edge to the centre, the axial electric field becomes uniform.**
- **From the centre upto 10 micron the electric field is uniform**
- **The edge effect distorts the electric field beyond that.**

Variation of electric field (Ex) on the mesh surface

Along the x direction

Four different shape of mesh hole





Surface side in the drift region ***Surface side in the amplification region***

The transverse electric field is significant at the edge

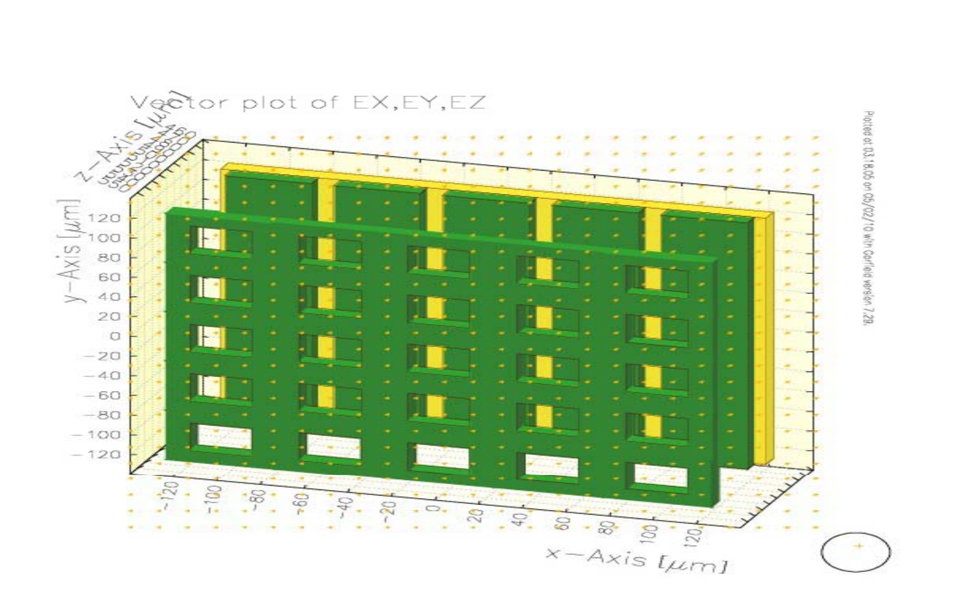
Using **GARFIELD** define a cell structure →

A drift plane ;

A micromesh of 5×5 hole ;

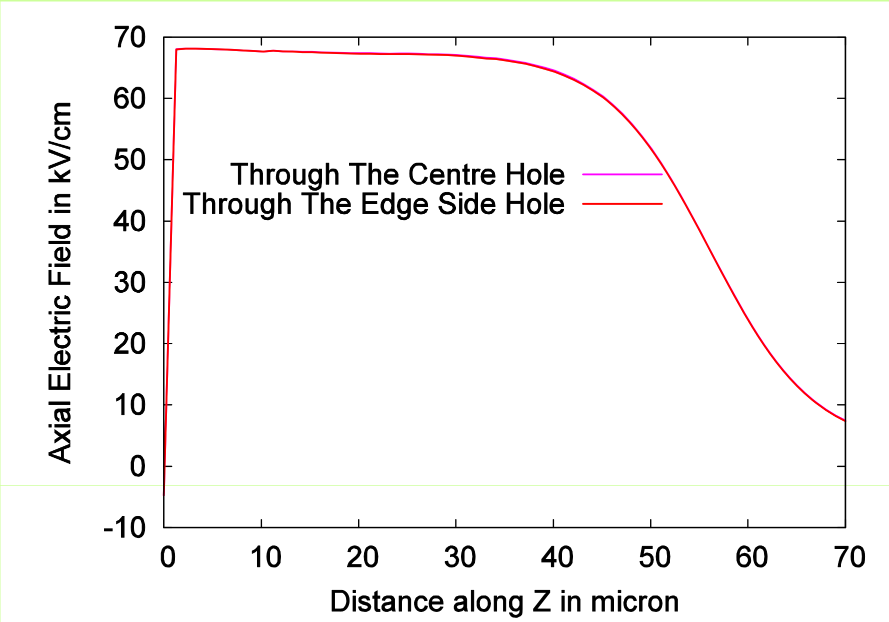
Five anode strip ;

A dielectric substrate ;



Using neBEM →

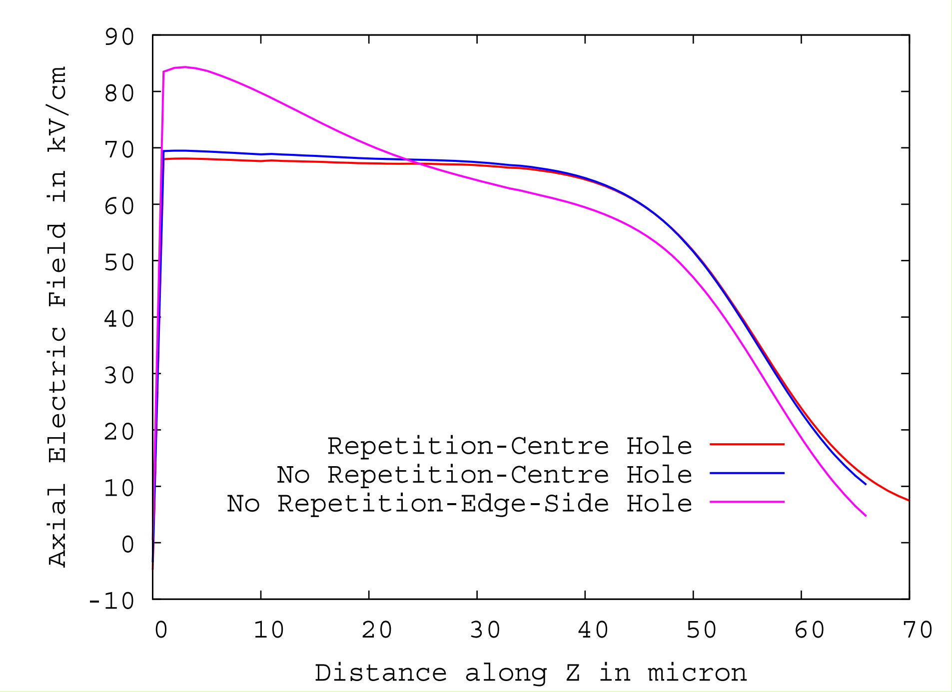
The whole cell structure is repeated along X and Y direction

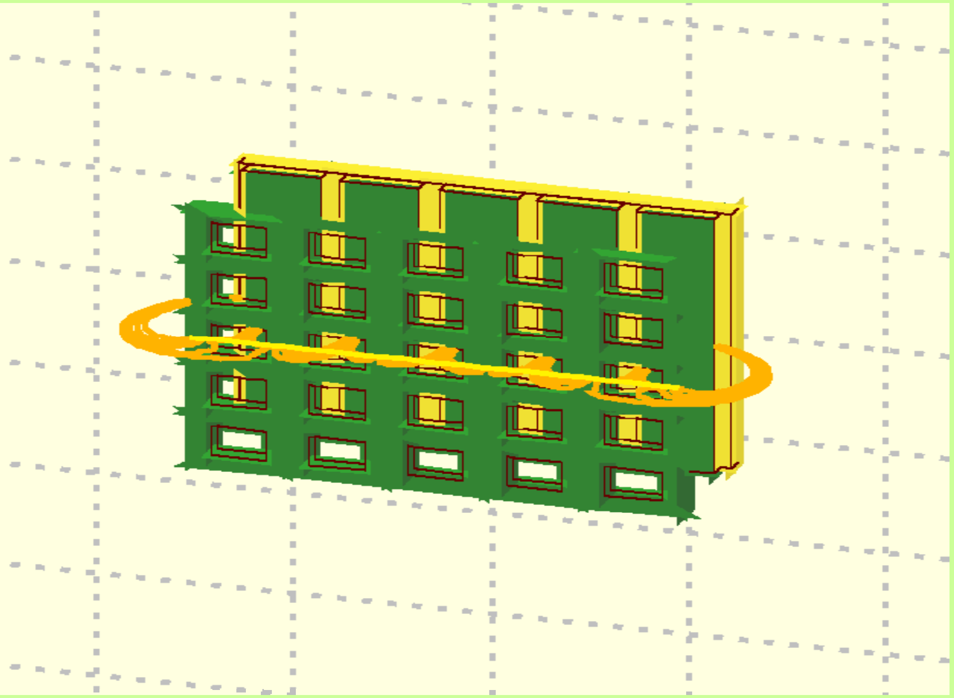


← In the amplification region the axial electric field are same for the central hole and for any edge side hole.

For the track , just above the mesh, gain ~ 1100

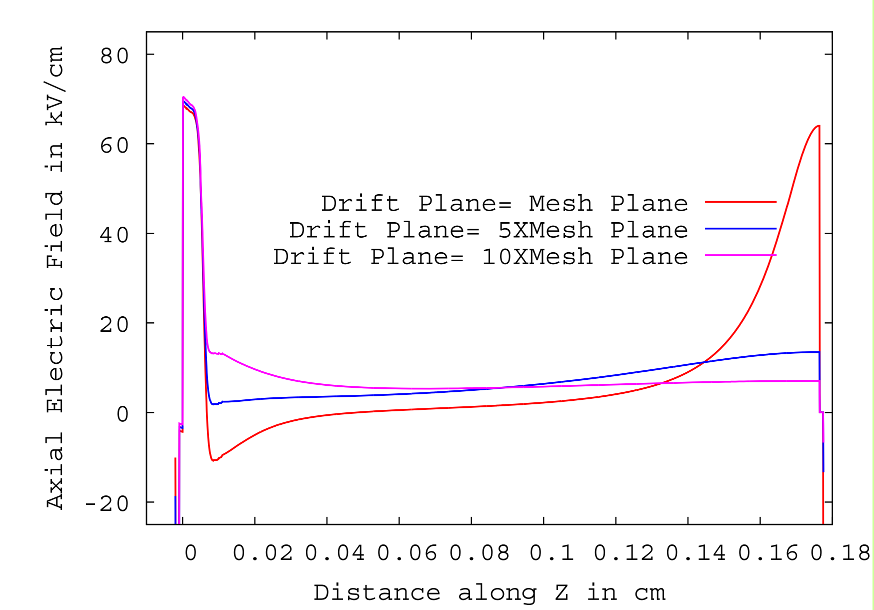
- Use the cell structure defined in previous cell
- No repetition along x and y direction





The axial electric field through the centre hole is different from any edge side hole →
At the edge the gain is affected

Use three different width of drift plane



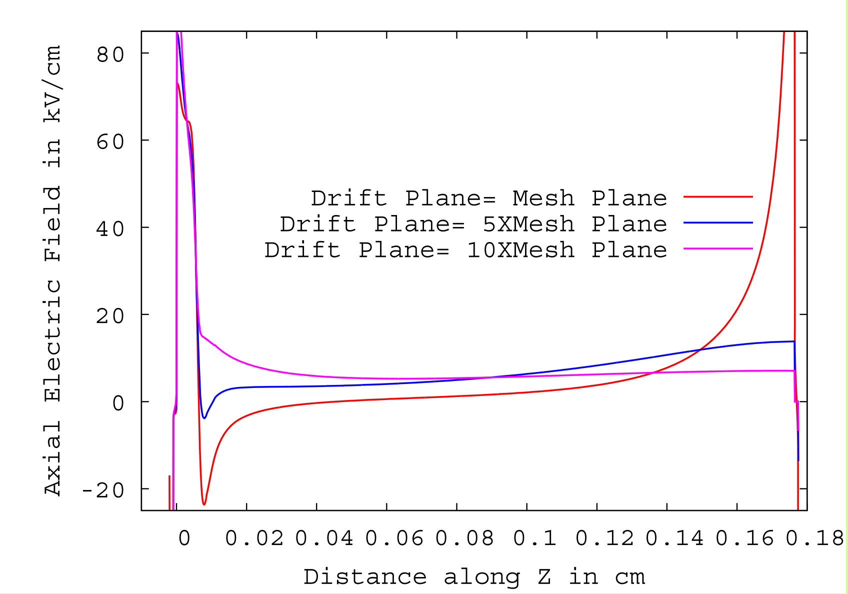
Central HOLE :-

Drift plane = mesh plane - just above the mesh, electric field is negative, electrons can't go to amplification region

Drift plane = 5×mesh plane - just above the mesh, electric field is positive , electrons can go to amplification region

Drift plane = 10× mesh plane - just above the mesh, electric field sharply increases

Electric field in drift region in 2nd and 3rd case are more uniform than that of 1st



EDGE SIDE HOLE :-

The electric field, just above the mesh becomes positive when Drift plane > 5×mesh plane

SUMMARY

- ✓ We have used the recently developed Garfield + neBEM + Magboltz + Heed combination to simulate Micromegas detectors

- ✓ In order to calculate gain along a pre-fixed line, we have used simple trapezoidal integration

- ✓ Variation of the shape of the mesh hole affects electric field and hence, gain. The electric field and gain both decrease as we go from N = 2 to N =16. Variation of shape also affects the transverse electric field

✓**Electric field also depends on the radius of the mesh hole. As we decrease the radius, the electric field in the amplification region becomes distorted and, hence, the gain also changes.**

✓**Change of the amplification gap for a particular mesh voltage and mesh hole radius changes the electric field and gain**

✓ **Significant edge effects distort the axial electric field near the detector edge**

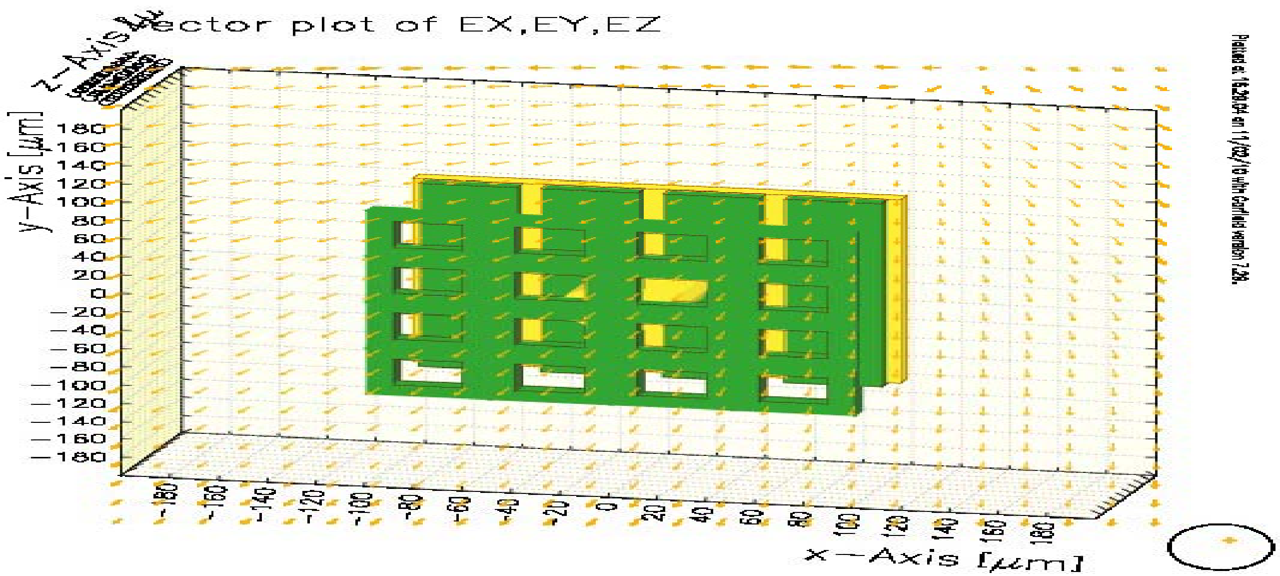
✓ **Size of the drift plane affects the uniformity of the electric field in the drift region**

FUTURE PLAN

❖ *To simulate performance of different variants of Micromegas detector (bulk, resistive, Ingrid, Gossip, multiple layer etc)*

❖ *To study the effects of different geometrical and electrical parameters*

❖ *To study the effect of spacers*



We happily acknowledge
the help / suggestions of

Rob Veenhof
and
other members of the RD51 collaboration